MEMORANDUM

To:	Leslie McLean, King County Alex Shkerich, Atelier	**Date:**	May 16, 2005
From:	Jennifer Lowe & Rob McKenzie	**TG:**	03292.00
cc:			
Subject:	Burke-Gilman Trail Crossing Plan		

This study responds to safety concerns that have been expressed by users of the Burke-Gilman Trail as well as drivers of vehicles who must cross the trail in order to access their residences. While no reported accidents were found, some deficiencies in the current signing and control measures at trail crossings were identified. This may be a result of placement of control without proper engineering. Those deficiencies raise concerns related to problematic sight distance at vehicular trail crossings and non-compliance with posted intersection control measures and questions about what type of control is appropriate at the vehicular crossings. This memo has been prepared to document existing vehicle crossing conditions along the Burke-Gilman Trail through the City of Lake Forest Park, and to propose recommended signing improvements for each crossing as the County makes plans for redesign of the section of trail that runs through Lake Forest Park. The graphic figures accompanying this memo detail the proposed signing for each of the crossings.

Existing Conditions

The Burke-Gilman Trail (Path) serves a wide variety of users including pedestrians, joggers, bicyclists, skaters, and wheelchair users. Within this variety of users, there exists a range of skill and experience levels. Young children, parents with strollers, and cyclists of differing experience use the trail. Bicyclists and pedestrians are at risk for greater severity of injuries than motorized vehicles where motorized and non-motorized paths cross. The concern is of particular focus along this Path due to the wide variety of users and travel modes. Site observations performed as part of this project showed that sight distance at many of the crossings is currently limited and warning and control signing at the trail crossings varies, contributing to conditions where many trail users disregard the current signing at the crossings.

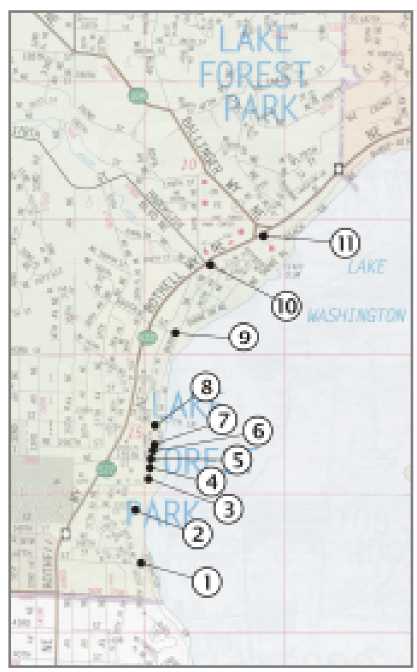


Figure 1- Study Intersections

The Transpo Group 11730 118th Avenue N.E., Suite 600 Kirkland, WA 98034-7120 425.821.3665
Fax: 425.825.8434

The study area for this project, shown in **Figure 1**, includes eleven locations where the Trail intersects with vehicle crossing locations. Eight crossing locations are driveways that provide an access point to less than 50 homes. One crossing location is an intersection with a higher-volume street serving as one of several access points to a residential area. The remaining two crossing locations occur at signalized intersections. The study area includes the area from NE 147th Street to the south and Ballinger Way NE to the north and all Path crossings in between. Summarized below are the existing signing and striping conditions for each of the study area crossing locations.

In this memo, the various crossings are referred to as "intersections," often without distinction between driveway crossings and standard intersections where a street crosses the trail. These crossings ("intersections") are numbered to help in identifying specific reference to location throughout the report.

Crossings

Intersection 1 (NE147th Street/Edgewater Lane)

Intersection 1 is located where NE 147th St crosses the Path. Edgewater Lane is parallel to, and located immediately to the east of the Path in this area. This crossing provides driveway access to approximately 39 homes located along Edgewater Lane south to 42nd Place NE.

Existing features of this crossing include the following:

Eastbound approach to intersection 1

- Stop control for both directions of Path traffic.
- Bicycle warning sign W11-1 at the eastbound intersection approach.
- Single hinged tubular markers along the Path centerline on each side of the roadway.
- No Path pavement markings of any kind.
- No advance warning signs of any kind.
- Shrubbery and trees on the east side of the Path combined with a slight roadway grade, sloping down from the intersection towards Edgewater Lane limits the departure sight-distance for westbound vehicles.

Intersection 2 (NE151st Street/Residential Driveways)

NE 151st St. splits into two separate driveways as it reaches the Path. The southern driveway provides vehicle access to one home and the northern driveway provides vehicle access to two homes.

While treated as one intersection, this intersection consists of two distinct crossing points. The driveway east of the Path at the southern crossing is characterized by a steep grade, sloping down towards Lake Washington. This grade combined with ivy covered fence that abuts the driveway opening, limits approaching and entering sight-distance to un-safe levels for vehicles exiting the driveway. The northern driveway is aligned so that crossing vehicles must cross the Path at an angle that creates sight-distance limitations and requires vehicles to be in the Path intersection longer than would be typical at a 90-degree crossing.

Eastbound approach to intersection 2

Existing features of this intersection include the following:

- Stop control for both directions of Path traffic.
- Multiple advance warning signs for Path users approaching from the south including; “warning- trail revisions ahead”, “caution vehicle traffic”, “caution crossings ahead” in combination with a 10mph speed limit sign, “caution hidden driveways ahead”, and MUTCD W3-1 stop ahead sign.
- Multiple advance warning signs for Path users approaching from the north including; “warning- trail revisions ahead”, “hidden driveways ahead use extreme caution”, and a 10mph speed limit sign.
- No warning or control signs for vehicles accessing the southern driveway

- Yield control for vehicles approaching the northern driveway from the west (This sign, in addition to the Stop sign for Path users, clearly conflicts with MUTCD standards regarding the use of only one type of regulatory control device at intersections).
- Single hinged tubular markers along the Path centerline on each side of the roadway. A striped, hatched diamond-shaped pattern painted on the pavement at the base of each tubular marker.
- Path pavement markings include:
    - Solid white lines indicating the Path edges through the intersection
    - A dashed yellow centerline through the intersection.
    - Rectangular areas outlined and hatched in yellow on the east side of the Path indicating driveway entrance areas.

Intersection 3 (NE153rd Street/Beach Dr NE)

Intersection 3 is an Adjacent Intersection type crossing where NE 153rd St crosses the Path. Beach Dr NE is parallel to, and located immediately east of the Path in this area. This crossing provides driveway access to 7 homes located along Beach Dr NE east of the Path.

Existing features of this intersection include the following:

Eastbound approach to intersection 3

- Stop control for both directions of Path traffic.
- Bicycle warning sign W11-1 at the eastbound intersection approach.
- Motor vehicle prohibited sign for vehicles looking south, down the Path.
- Single hinged tubular markers along the Path centerline on each side of the roadway.
- Path is striped with a crosswalk treatment through the intersection.
- No advance warning signs of any kind.

- Shrubbery, trees, and hedges on the east side of the Path limit the departure sight-distance for westbound vehicles. Shrubs and trees on the west side of the Path are sight-distance obstacles for eastbound drivers.

Intersections 4-7 (Residential Access Drives North of NE 153rd Street)

Intersections 4-7 are a cluster of residential access drives located between the intersections at NE 153rd St and NE 157th St. These four intersections occur within a distance of less than 410'. These four crossings provide vehicle access to a total of eleven homes located east of the Path.

Existing features of these crossings include the following:

Northbound Path approach to intersection 4

- Stop control signs for southbound Path traffic at intersections 4, 5, and 7.
- Stop control signs for northbound traffic at intersections 4, 5, and 6.
- Bicycle warning sign W11-1 at the eastbound intersection approach for intersection 7.
- Bicycle warning sign W11-1 oriented to be viewed by southbound Path traffic at intersections 4 and 5.
- "Caution hidden driveways ahead" signs for Path users approaching from the south, in advance of intersections 4 and 5.
- Single hinged tubular markers along the Path centerline on each side of driveway 4. One, single hinged tubular marker along the Path centerline north of intersection 7.
- No crosswalk striping treatment at any of these intersections.
- Shrubbery, trees, and hedges on the east side of the Path limit the departure sight-distance for westbound vehicles. Shrubs and trees on the west side of the Path are sight-distance obstacles for eastbound drivers.

Intersection 8 (NE157th Street/Residential Access Drive)

Intersection provides driveway access to 4 homes located directly east of the Path.

Existing features of this crossing include the following:

- Yield control for both directions of Path traffic.
- Bicycle warning sign W11-1 at the eastbound intersection approach.
- No Path pavement marking of any kind.
- No advance warning signs of any kind.
- Sight distance obstacles in this area include; hedges and fence near southeast corner, and hedges near northeast corner.

Intersection 9 (NE165th Street/Beach Dr NE)

Intersection 9 occurs where NE 165th St crosses the Path and intersects with Beach Dr NE. Beach Dr NE is parallel to, and located immediately to the east of the Path in this area. This crossing is one of two access roads to the Sheridan Beach neighborhood. All-way stop control is currently in place for all vehicles approaching this intersection.

Existing features of this intersection include the following:

- Stop control for both directions of Path traffic and for vehicles on the east/west legs as well.
- Bicycle warning sign W11-1 at both the eastbound and westbound approaches.
- Single hinged tubular markers along the Path centerline on each side of the roadway.
- Path is striped with a crosswalk treatment through the intersection.
- No advance warning signs of any kind.
- Trees and hedges on the southwest

Eastbound approach to intersection 9

corner of this intersection are sight-distance obstacles for eastbound drivers.

Intersection 10 (Bothell Way NE/NE 170th Street)

Northbound Path approach to intersection 10

Northbound Path approach to intersection 10

The Path crossing for intersection 10 occurs as part of the signalized intersection located at Bothell Way NE and NE 170th St. The Path crosses NE 170th St on the east side of Bothell Way.

Existing features of this intersection include the following:

- Signalized control for all vehicle and non-motorized intersection approaches.
- Push-button actuated pedestrian signals f
- Stop signs for Path users are located where the Path joins the sidewalk.
- "Stop Ahead" warning sign for southbound Path traffic in advance of intersection.
- Crosswalk striping on the roadway through the intersection.

Intersection 11 (Bothell Way NE/Ballinger Way NE-Beach Dr NE)

Northbound Path approach to intersection 11

The Path crossing for intersection 11 occurs as part of the signalized intersection located at Bothell Way NE and Ballinger Way NE/Beach Dr NE. The Path crosses Beach Dr NE on the east side of Bothell Way.

Existing features of this intersection include the following:

- Signalized control for all vehicle and non-motorized intersection approaches.
- Push-button actuated pedestrian signals for Path users.
- "Caution heavy vehicle traffic" warning sign for northbound Path traffic in advance of intersection.
- "Obey Crosswalk Signal" sign for both directions of Path traffic located on the opposing intersection corners (see photo).

- Crosswalk striping on the roadway through the intersection.

Trail Volumes and Composition

As part of this analysis, trail volumes were collected on Wednesday, June 2, Thursday, June 3 and Saturday, June 5. On these days, from 7:00 AM to 7:00 PM, in two different locations all users of the trail were counted and categorized as bicyclists, pedestrians, skaters and others. Attachment 1 provides the raw data collected, while Table 1 summarizes those findings.

Table 1. Trail Users

Burke-GilmanTrail at NE 147th Street (Edgewater Lane)			
	Wed, June 2	Thurs, June 3	Saturday, June 5
12 Hour Total	1,262	1,361	1,496
% Pedestrian	16.56%	16.31%	12.57%
% Bicycles	77.65%	80.16%	79.14%
% Skates	1.74%	0.59%	0.67%
% Other	4.04%	2.94%	7.62%
Peak Hour	4:30 to 5:30 PM	5:45 to 6:45 PM	11:45 am TO 12:45 pm
Total Peak Hour Volume	209	226	196
% During Peak	17%	17%	13%
Burke-Gilman Trail at NE 165th Street (Beach Drive NE)			
	Wed, June 2	Thurs, June 3	Saturday, June 5
12 Hour Total	1,283	1,364	1,418
% Pedestrian	14.50%	13.86%	15.94%
% Bicycles	82.77%	85.19%	82.65%
% Skates	1.95%	0.95%	1.41%
% Other	0.78%	0.00%	0.00%
Peak Hour	4:30 to 5:30 PM	5:45 TO 6:45 pm	11:45 am TO 12:45 pm
Total Peak Hour Volume	210	237	196
% During Peak	16%	17%	14%

As the data shows, over ¾ of the trail users are bicyclists.
Pedestrians compose from 13% to 17% of trail users.

Roadway Volumes

Roadway volumes for motor vehicles crossing the Path at residential driveways and residential access drives are derived from Institute of Transportation Engineers (ITE) trip generation calculations for "single-family detached housing." These calculations characterize the average number of trips generated per day by single-family homes for both weekday and weekend (Saturday) scenarios. According to ITE, it is expected that the average single-family home generates 9.57 trips per day on a weekday and 10.1 trips per day on a Saturday. Calculations for this plan round both of these numbers to 10. For access drives, the number of vehicle crossings is equal to the number of homes multiplied by 10.

The data collected on trail utilization indicated that, over a 12 hour period at the two locations of data collection, the trail served from 980 to 1,184 bicyclists. In comparison, study intersections 1 through 8 serve between 1 and 39 homes on the east side of the Path. This means that according to ITE trip generation calculations, the highest number of vehicle crossings at any one of these intersections is approximately 390 vehicles. When compared to only bicyclists during a similar (12-hour) time period, it was observed that Path utilization was nearly 3 times as high. This indicates that fewer than 50 vehicles will cross the adjacent Path during any 24-hour period. Path users may rarely, if ever encounter vehicles crossing at these driveways. According to the MUTCD, compliance to regulatory signs in such situations is not likely. The data on bicyclists' compliance with posted stops on the trail confirm this assumption.

Bicycle Stop Compliance

In addition to collecting and categorizing the count data on June 2, 3, and 5, observations were made of bicyclists' compliance with the stop signs at the intersections in the location where the counts were collected. The data on stop compliance is also provided in Attachment 1. The compliance observed was very low. Though many bicyclists were observed to slow down in advance of these intersections, less than three-percent of the bicycles came to a full stop before proceeding through the intersection.

Bicycle Speeds

On the same days, June 2, 3 and 5, data was collected on the traveling speed of bicycles at a location south of NE 151st Street. Bicycle travel speeds were measured on a random sampling of a total of 500 bicyclists over a three day period. Speed data and methodology for sample size determination are offered in Attachment 2. The data indicated that:

- 84% of the bicyclists were traveling over the posted speed limit of 10 miles per hour

- The average bicycle speed was 13.6 mph
- The speed at which 85% of the bicyclists were at or under (85th percentile) was 17 mph. 15% of the bicyclists travel at a higher speed.
- Bicycle travel speed ranged from 5 to 21 mph

Accident History

The City of Lake Forest Park Police Department has jurisdiction over the portion of the trail that runs through this City. As such, may respond to any accidents along the trail that are reported. The County Sheriff's Department stated that they would refer any reports of accidents along the trail to the local Police Department. Individual accident records that had been filed at the Lake Forest Police Department from January 2000 to date (May 16, 2005) were personally examined for this analysis. While no accidents were found on Burke Gilman Trail, there was one vehicle pedestrian accident at Beach Drive where a bicyclist did not stop at a stop sign. No other vehicle/bicycle accidents or pedestrian/vehicle accident reports on the Burke-Gilman Trail or cross streets in the vicinity immediately adjacent to the bike trail were found to be on file at the Lake Forest Police Department. However, there is anecdotal evidence that there have been at least a few accidents where bicycles and vehicles have collided. The Eastside Public Communications Agency, located out of the Crossroads Fire Department is the agency responsible for responding to 911 calls for this area. They contact the Shoreline Fire Department Dispatch and the Northshore Fire Departments for dispatch of medic and fire responses in this area. Both of these agencies were contacted. The Northshore Fire Department Battalion Chief went manually through records back to 1999 as well as talked to several of his staff. For accidents on the trail he found 3 in 1999, 3 in 2000, none in 2001, 2 in 2002, 3 in 2003, then 1 in 2004. He said it's probably safe to estimate that there are about 3 per year severe enough to warrant call of an aid car, though the staff thinks there may be less severe ones that never get reported. Not all of the calls to which they responded were vehicle/pedestrian accidents. As far as location, he suspects that near Log-Boom park in Kenmore (out of our study area) is highest. Within the study area, he thinks the light at Ballinger Way may be where many of the accidents are concentrated. He suspected that was because bicyclists are not looking for turning vehicles. The Medic and Fire Department file a Medical Incident Report Form with King County Health Department. The Health Department was contacted to see if reports of accidents in this area could be reviewed. Privacy rights do not allow review of individual Health Department records. There is no data base that identifies accident reports by location so it was not possible to trace incident reports through this source. While it is possible that there may have been some minor accidents that weren't reported, or "near misses" as reported by neighbors and users of the trail, no official records of those incidents have been found in Police Department or County Health records. State law only requires that an incident report be completed if more than $700 of damage is incurred, in which an accident form should be filed with WSDOT. Accident data has been requested from WSDOT.

Signage History

The Burke-Gilman Trail Supplement to the Final Environmental Impact Statement issued in July, 1975, states:

> *"Motorized vehicles will be granted the right-of-way at all intersections. Regulation stop signs will be posted along the trail approachment to these intersections. The alternative of allowing right-of-way to the bicyclist and pedestrian is considered too dangerous, particularly during dusk and early evening hours.*
>
> *"The trail right-of-way crosses existing streets and driveways to private dwellings at a number of points. Prior to purchase by King County, access to these residences was granted by short-term permits which could be canceled on brief notice. The County is currently attempting to formalize new use agreements for the driveways to these residences."*

An intersection is defined as the common area where two or more streets come together. When the trail was originally designed and constructed, bicycles and pedestrians were stopped at all street intersections with the trail. Private crossings of the trail were not considered street intersections and were not signed or controlled, as the trail was granted right-of-way. Any controls at private driveways or multiple private driveways may have had either stop or yield controls installed for the cars, depending upon sight lines. The subsequent placement of stop control years after construction of the trail at several private driveways is contrary to current standard engineering practice and was not a part of the trail's original design and construction. No record of an engineering study related to this subsequent placing of stop signs has been located. Discussions with County staff indicate that the placement of stop control for trail users at private driveways was based upon the direction of a former King County Councilmember, in response to requests from residents.

Traffic Control Standards

The *Manual of Uniform Traffic Control Devices* (MUTCD) (U.S. Department of Transportation, Federal Highways Administration, 2003) is adopted by reference in accordance with title 23, United States Code, Section 109(d) and Title 23, Code of Federal Regulations, Part 655.603, and is approved as the national standard for designing, applying, and planning traffic control devices. These regulations specify the adoption of the MUTCD as the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel.

The basic principles that should be observed when designing any type of traffic control are defined by the MUTCD: *"to be effective, a traffic control device should meet five basic requirements: fulfill a need, command attention, convey a clear simple meaning, command respect from road users and give adequate time for proper response."*

The MUTCD also provides guidance on the importance of uniformity: *"uniformity of devices simplifies the task of the road user because it aids in recognition and understanding, thereby reducing perception/reaction time. Uniformity means treating similar situations in a similar way. The use of a uniform traffic control device does not, in itself, constitute uniformity. A standard device used where it is not appropriate is as objectionable as a nonstandard device; in fact, this might be worse, because such misuse might result in disrespect at those locations where the device is needed and appropriate".* It is noted that this study focuses on a limited section of the Burke-Gilman Trail. Ideally, similar approaches would be applied throughout the trail system in order to provide the uniformity that is helpful for both Path users and drivers in anticipating and obeying crossing controls. Within the City of Seattle, and elsewhere along the Burke-Gilman Trail, where minor "local access" roads intersect the trail the trail is treated as the major crossing. While stop control is not provided to vehicles on every location where trail and roadway cross, even where adequate sight distance may not be available, in locations where there is a safety concern, motor vehicles are typically stopped or must yield to crossing bike traffic.

Standards for Placement of Intersection Controls

The complex nature of mixed-mode intersections requires establishment of a clear right-of-way priority. Identifying the "major" and "minor" intersection legs defines right-of-way priority. The two main factors in identifying the major and minor intersection legs are roadway volumes and travel speeds. Typically, the appropriate intersection control device (traffic signal, stop sign, yield sign, etc.) gives the major leg priority by controlling or limiting traffic movements of the minor leg. Conditions at intersections must meet a number of criteria prior to the application of the appropriate intersection control device.

Right-of-way Priority

Given the roadway volume, Path utilization data, and travel speed data presented previously, it is assumed that the Path shall be designated the major intersection leg at minor streets that provide residential access to fewer than 100 homes or other conditions prevail.

The MUTCD provides guidelines for determining the appropriate regulatory sign to utilize as an intersection control device. In regards to regulatory signs the MUTCD states:

- *Regulatory signs should be used conservatively because these signs; if used to excess, tend to lose their effectiveness*
- *STOP signs should not be used for speed control*
- *STOP signs should be installed in a manner that minimizes the number of vehicles having to stop*
- *In most cases, the street carrying the lowest volume of traffic should be stopped, if stop control is warranted*

- *A STOP sign should not be installed on the major street unless justified by a traffic engineering study*

For driveways, the existing signage conflicts with State regulations, as can be found in the Washington State Driver's Manual, which states that:

> *"There will be many times when you will need to slow down or stop your vehicle to allow another vehicle, pedestrian, or bicyclist to continue safely. Even if there are no signs or signals to regulate traffic, there are laws governing who must yield the right-of-way.*
>
> *The law says who must yield the right-of-way; it does not give anyone the right-of-way. You must do everything you can to prevent striking a pedestrian or another vehicle, regardless of the circumstances.*
>
> - *Drivers crossing a sidewalk while entering or exiting a driveway, alley or parking lot must stop and yield to pedestrians. It is illegal to drive on a sidewalk except to cross it*
> - *Drivers entering a road from a driveway, alley, parking lot or roadside must yield to vehicles already on the main road."*

While the existing signage does stop bicycles and vehicles at street intersections (intersections 10 and 11), signage does not conform to standards established in the State drivers' manual for driveway crossings.

As noted, engineering design guidelines for signage and traffic control measures are based on the foundational principal that "less is better." Signs should be kept to a minimum so as not to confuse or distract roadway users. More restrictive controls, such as stop signs and traffic signals should only be placed if defined warrants are met. Warrants are typically based on minimal volumes, imbalance of volumes, delay and safety issues. If minimal warrants are not met, the devices are typically not permitted. Unwarranted restrictions lead to disregard.

Crossing Treatment Design Approach

There are two areas of consideration that must be addressed in the preparation of crossing treatment design: sight distance and traffic control (including both signing and pavement markings). Adopted standards for each of these areas are summarized in this section.

Sight Distance Standards

Prior to entering an intersection, both Path users and drivers require time to process the decision as to whether or not it is safe to enter the intersection. The distance over which the potential danger is perceived and reacted to is called sight distance. At crossings, the required sight distance is based on the minimum clear field of sight needed for approaching traffic to perceive the danger and to take the necessary precautions to avoid conflict. Obstructions to meeting sight distance standards at crossings within the study area include: vertical limitations of driveways and roads on steep grades; horizontal curves in roadways and the trail; and the presence of trees, foliage, utility poles, fences, and other objects at the crossings.

The *Geometric Design of Highways and Streets, 4th ed. (Green Book)* (AASHTO, 2001) and *Guide for the Development of Bicycle Facilities* (AASHTO, 1999) both provide guidance for calculation of adequate stopping sight distance. Sight distance calculations are based on approach speeds to the intersection or crossing. WSDOT Design Manual, Chapter 1020, Bicycle Facilities recommends the design speed for a shared use path in urban areas, with grades less then 4% as 20 MPH. This is consistent with The *Guide for the Development of Bicycle Facilities,* which also suggests using 20 mph as the *design* speed for multi-use paths. The design speed affects the recommended stopping sight distance in this case. Design criteria are given in five mph increments. A design speed of 15 mph would accommodate less than 75% of the bicycle riders. The <u>Policy on Geometric Design of Highways and Streets</u>, American Association of State Highway and Transportation Officials (AASHTO, 2004) notes that "the selected design speed should fit the travel desires and habits of nearly all drivers expected to use a particular facility." Also, "It is desirable that the running speed of a large proportion of drivers be lower than the design speed." While the policy is related specifically to vehicle travel, there is no indication that a similar policy should not apply to bicycles.

For vehicle traffic, typically, *posted* speed limits are not the highest speed used by drivers. AASHTO notes that posted speed limits are usually set to approximate the 85th percentile speed of traffic. On the trail, the 85th percentile bicycle speed was 17 mph. However, due to the mix of users on the trail, including bicycles, pedestrians, and skaters, the overall travel speeds are less than those for just bicycles. It would be appropriate to post speeds at a rate lower than just the bicycle speeds. 10 to 15 mph would be an appropriate *posted* speed limit for this section of the trail. The posted speed limit of 10 MPH is within this range.

Stopping Sight Distance

According to the *Green Book*, "for intersections not controlled by yield signs, stop signs, or traffic signals, the driver of a vehicle (or bicycle) should be able to see potentially conflicting vehicles (or bicyclists) in sufficient time to stop before reaching the intersection." Additionally, "field observations indicate that vehicles approaching uncontrolled intersections typically slow to approximately 50 percent of their midblock running speed." In fact, at the study intersections, approaching vehicles were observed to slow to nearly a stop (less than 5 mph) as they approach the trail.

Creation of clear sight distance triangles will provide adequate distance so that approaching vehicles can stop prior to the intersection if they see any approaching trail users. Bicyclists need to be able to stop prior to reaching the intersection in case an obstacle, such as a stalled vehicle, is blocking the trail. Only when adequate stopping sight distance for the bicycles cannot be achieved should path traffic be stopped. In such cases all legs of the intersection, the path and vehicular legs should be stopped using the recommended signage.

Figure 1 illustrates the sight distance triangle for which leg lengths are calculated.

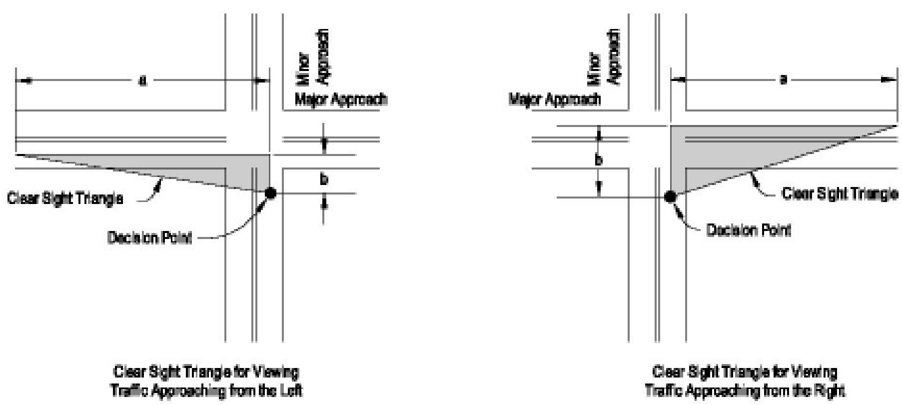


Table 2 gives the calculation for vehicular stopping sight distance from the intersection as extrapolated from AASHTO.

Table 2. Calculation of Vehicle Stopping Sight Distance in Feet

Vehicle Stopping Sight Distance	
"a" Leg Length	
Auto Speed	Bicycle Speed 20 mph
3	19.0'
5	31.7'
10	63.4'
15	95.1'
20	126.7'
25	158.4'

Bicycle stopping sight distance is calculated based on a formula that takes into consideration the speed of the bicycle and coefficient of friction and slope of trail.[1] Table 3 provides the calculations for determining the bicycle stopping sight distance.

Table 3. Calculation of Bicycle Stopping Sight Distance

Bike Stopping Sight Distance	
"b" Leg Length	
$S=((V^2)/(30(f+/-G)))+3.67V$	S=stopping sight distance (ft)
	V=velocity (mph) (20 mph assumed)
$S=((20^2)/(30(0.25+/-0G)))+3.67(20)$	f=coefficient of friction (use 0.25)
S=126.7'	G=grade ft/rise or run)

Based on the calculations in Tables 2 and 3, the recommended sight triangle is 19 feet from the intersection on the minor approach (vehicular) and 127 feet from the intersection on the major approach (trail).

The trail design should incorporate these sight distances wherever possible at all vehicular trail crossings in the study area, except intersections 10 and 11.

The trail crossing at intersections 10 and 11 are incorporated into those signalized intersections. Signal heads control all vehicular and trail traffic at these crossings. Pedestrians and bicyclists using crosswalks are at risk from vehicles turning right on red because right-turning vehicle drivers are primarily focused on potential conflict with through vehicular traffic from their left and don't look to the right. Because of the high trail volumes on the trail at these intersections, safety for trail users could be improved by restricting northbound vehicles from making a right turn on red. Further analysis of the impacts of this modification are outside the scope of this analysis but should be explored.

[1] Guide for the Development of Bicycle Facilities, American Association of State Highway and Transportation Officials, 1999.

Pavement Markings

The *Guide for the Development of Bicycle Facilities* and the MUTCD both provide guidelines to signing and marking treatments for intersections on shared use paths.

AASHTO states that *"pavement markings at a crossing should accomplish two things: channel path users to cross at a clearly defined location and provide a clear message to motorists that this particular section of the road must be shared with other users"*. These goals guide the treatments recommended as part of the recommended approach. The main pavement marking treatments recommended in this plan are stop lines and crosswalk markings. In addition to pavement markings, hinged tubular markers are also recommended as part of this plan at most crossing locations.

Crosswalk Markings

The MUTCD provides the following support for the use of crosswalk markings: "Crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops. Crosswalk markings also serve to alert road users of a pedestrian crossing point across roadways not controlled by highway traffic signals or STOP signs."

Tubular Markers

AASHTO's *Guide for the Development of Bicycle Facilities* states the following in regard to restricting motor vehicle traffic on shared use paths:

> *"Shared use paths may need some form of physical barrier at highway intersections to prevent unauthorized motor vehicles from using the facilities. Provisions can be made for a lockable, removable (or reclining) barrier post to permit entrance by authorized vehicles. Posts or bollards should be set back beyond the clear zone on the crossing highway or be of a breakaway design."*

Figure 4 provides details of pavement markings and the hinged tubular marker details that are used to prevent unauthorized motor vehicles from using the trail.

Traffic Control Signs and Pavement Marking Options

The following signing and pavement marking options are provided for consideration and use, when justified according to the checklist. The following section provides details regarding recommended signs and markings including MUTCD guidance where applicable.

Yield Sign (R1-2)
YIELD signs may be used instead of STOP signs if engineering judgment indicates that one or more of the following conditions exist:

A. When the ability to see all potentially conflicting traffic is sufficient to allow a road user traveling at the posted speed, the 85th-percentile speed, or the statutory speed to pass through the intersection or to stop in a reasonably safe manner.

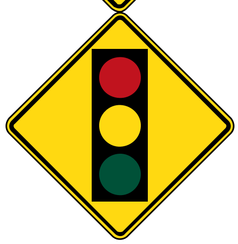
B. If controlling a merge-type movement on the entering roadway where acceleration geometry and/or sight distance is not adequate for merging traffic operation.

C. The second crossroad of a divided highway, where the median width at the intersection is 9 m (30 ft) or greater. In this case, a STOP sign may be installed at the entrance to the first roadway of a divided highway, and a YIELD sign may be installed at the entrance to the second roadway.

D. An intersection where a special problem exists and where engineering judgment indicates the problem to be susceptible to correction by the use of the YIELD sign.

Stop Sign (R1-1)
STOP signs should be used if engineering judgment indicates that one or more of the following conditions
exist:
A. Intersection of a less important road with a main road where application of the normal right-of-way rule would not be expected to provide reasonable compliance with the law;
B. High speeds, restricted view, or crash records indicate a need for control by the STOP sign.

4-Way or All-way Plaque (R1-3 and R1-4)
The following criteria should be considered in the engineering study for a multiway STOP sign installation:
A. Locations where a road user, after stopping, cannot see conflicting traffic and is not able to reasonably safely negotiate the intersection unless conflicting cross traffic is also required to stop.

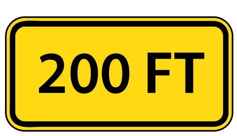


Advance traffic control signs (W3-1) Stop Ahead and (W3-3) Signal Ahead
The Advance Traffic Control symbol signs include the Stop Ahead (W3-1) and Signal Ahead (W3-3) signs.

An Advance Traffic Control sign may be used for additional emphasis of the primary traffic control device, even when the visibility distance to the device is satisfactory.

Intersection Warning (W2-1)
A Cross Road (W2-1) symbol may be used in advance of an intersection to indicate the presence of an intersection and the possibility of turning or entering traffic.

Intersection Warning sign (W2-1) should not be used on approaches controlled by STOP signs, YIELD signs, or signals.



Distance Warning Plaque (W16-2a)
A supplemental plaque may be displayed with a warning sign when engineering judgment indicates

that road users require additional information beyond that contained in the main message of the warning sign.

The Distance Ahead (W16-2 series) plaque may be used to inform the road user of the distance to the condition indicated by the warning sign.

This plaque is recommended due to its benefit to Path users traveling at different speeds.

Ahead Plaque (W16-9p)
A supplemental plaque may be displayed with a warning sign when engineering judgment indicates that road users require additional information beyond that contained in the main message of the warning sign.

No Motor Vehicles (R5-3)
Selective Exclusion signs give notice to road users that State or local statutes or ordinances exclude designated types of traffic from using particular roadways or facilities.

Bicyclists use Pedestrian Signal Sign(R9-5)
The R9-5 sign may be used where the crossing of a street by bicyclists is controlled by pedestrian signal indications.

Intersection Warning (W2-1) with Look Plaque
At all crossings where the sight distances are met, the standard MUTCD intersection warning sign

(W2-1) shall be installed approximately 200 feet prior to the crossing, along the Path. Since Washington State law indicates that all vehicles must yield to bicyclists and pedestrians at any crossing, no additional signing is required for non-signalized crossings and the MUTCD does not provide any additional guidance. However, because site observations have shown that pedestrians and bicyclists are often distracted while traveling along the trail, it is recommended through this engineering study that the intersection warning (W2-1)/look sign be located immediately in advance of every crossing along the Path that is not controlled by another method of traffic control (such as a stop sign, yield sign, or signal).

The look plaque is recommended for use by the MUTCD at pedestrian approaches to rail crossings. The situation recommended here is similar, where pedestrians and bicyclists are advised to exercise caution and look before entering the intersection.

The look plaque would be black text on a white background.

Recommendations

Current conditions along the Burke-Gilman Trail do not meet best engineering safety practices. While reported accidents are minimal, it would be prudent to incorporate best engineering safety practices in any trail redesign. Redesign of the trail should incorporate adequate sight distance wherever possible. In addition, trail and roadway signage should be modified to reflect best engineering practices, as described in this report. As previously described, the existing sight distance is often limited at roadway crossings of the Path, particularly for westbound vehicles. The existing signing and striping is not uniformly applied or warranted, and users have been observed not complying with the existing traffic control. Based on the estimated vehicle and path volumes, the major approaches are the north/south approaches, or the Burke-Gilman trail. As such, control should be provided at the vehicular legs wherever adequate departure sight distance can be achieved. Uniform markings should be provided for trail users to warn of crossing vehicular traffic in such cases. Traffic should be stopped only when adequate sight distance cannot be achieved. Where multiple driveways cross the path in close proximity, efforts should be made to consolidate those driveways wherever possible, in order to minimize the number of places where there is potential for conflict.

The following list of improvements for path/driveway intersections has been developed as a framework for determining improvement recommendations for the signage along the trail. The list is given in order of importance. For each intersection, the approach is to start at the top of the list and determine which measures can be accomplished. .

The checklist is based on the following assumptions:

- The Path is designated as the major approach at residential driveways and access drives
- Vehicular speeds on trail approaches are very low
- The preferred crossing control is for vehicular traffic to yield to approaching trail traffic if adequate stopping sight distance for vehicles and bicycles is achievable.

Checklist (items listed by priority)

1. Limit points of conflict by consolidating driveways where possible.
2. Wherever possible provide adequate intersection sight distance at intersections by removing obstacles to sight distance and re-aligning the Path and/or roadways to maximize clear lines of sight.
3. When the needed sight-distance for vehicles on the minor leg approach can be provided, vehicular traffic should yield to crossing trail traffic. The yield sign is recommended as advised in the MUTCD "When priority is assigned, the least restrictive control that is appropriate should be placed on the lower priority approaches. STOP signs should not be used where YIELD signs would be acceptable. If neither bicycle nor vehicle site distance can be achieved then all legs should be stopped. (See Figures 5 and 6)
4. Place the appropriate regulatory traffic control signs at all intersection legs in accordance with AASHTO and MUTCD guidelines. Provide stop bars on the pavement when placing stop control.
5. Place hinged tubular markers in center of path at intersections to prevent vehicular use of trails.
6. Enhance awareness at intersections through the addition of crosswalk-type striping treatments at all Path/driveway intersections.
7. Provide warning signs for both motorists and Path users in advance of intersections in accordance with the MUTCD.

Figures 5 and 6 illustrate generically the recommended control markings and signage plan based on the described recommendations.

Recommended Study Area Crossing Traffic Control

Based on the review of the existing conditions, defined sight distance requirements, traffic control standards, and the recommended approach, the following crossing treatment designs are proposed for the Burke-Gilman Trail through Lake Forest Park. Ideally, the underlying principles should be applied to all crossings along the trail. The proposed treatments are separated into three categories: crossing with a local residential access, crossing with a neighborhood access, and crossing at a signalized intersection.

Crossing a Local Residential Access

At existing residential access crossings, intersections 1 through 8, if possible all obstacles to vision within the needed stopping distance sight triangle should be removed. To the extent possible, multiple driveways at any of these intersections should be combined. Figures 7 through 11 provide the recommended signage plans at these intersections if the required sight distance can be achieved. These figures are illustrative of the concept only. Larger, to scale, design drawings will specifically provide the layout for these site triangles.

Crossing a Neighborhood Access

Intersection 9 is the only crossing of this type in the study area. At this location, sight distance is not currently met and due to physical constraints, it is not likely to be met. The proposed traffic control plan, assuming sight distance remains constrained, appears in Figure 12.

Crossing at a Signalized Intersection

Sight distance does not affect Path operations at intersections controlled by traffic signals. The proposed traffic control plan recommends minimal changes at these locations, mostly dealing with uniformity. These recommendations are shown in Figures 13 and 14. As noted, a restriction for right-turn-on-red may be appropriate for northbound vehicles on Bothell Way. Impacts to vehicular traffic would need further analysis.

Treatments Considered but Not Recommended

Some features occasionally used to address sight distance-related issues at intersections and driveways include convex mirrors and actuated pole-mounted or in-pavement flashing warning lights. While these measures may provide added visibility, they should not be relied on for primary control at these trail crossings.

Installation of convex mirrors to provide vehicles with a view of trail traffic is not recommended because of the distortion in distance that the lens creates. Additionally, convex mirrors have limited sight distance and do not always provide a complete field of view, particularly with regard to objects moving at a range of speeds (pedestrians and bicycles for example). Mirrors can often interfere with traffic due to the amount of glare they reflect. Typically, mirrors are not allowed to substitute for required sight distance. Their use is primarily limited to existing low volume private roads with very low travel speeds built prior to requiring approval based on engineering standards for sight distance.

Another traffic control device considered was an ***actuated warning*** for bicyclists that would require them to stop if a vehicle were approaching a crossing. This is not recommended because the slow travel speed of vehicles and limited length of vehicular approach would not allow enough warning for the faster traveling bicycles to stop. Maintenance and monitoring of actuated warning signs is a concern. Failure of these actuated warning lights can result in more serious danger than if they were not used at all. The actuated flashers could supplement the recommended approach but should not replace the need for the vehicles to give the trail crossing priority.

Providing actuated warning to vehicular approaches when there is approaching trail traffic is difficult because of the difficulty in sensing all types of trail users. Pavement sensors do no usually work for sensing bicycles. The sensitivity of above ground motion sensors is likely to give false warnings. They also can easily become misaligned so that all motion is missed.

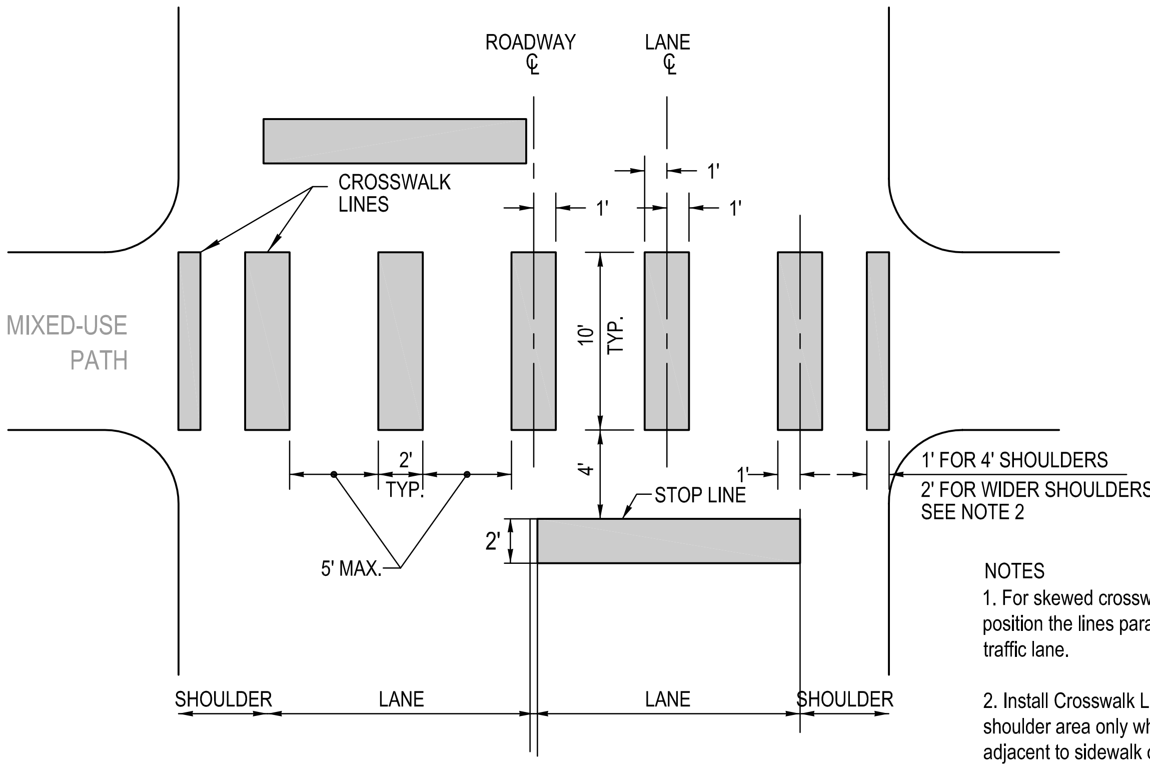
Modification to trail and roadway alignment to slow down bicycle speeds on the trail were considered. However, ITE's Traffic Control Devices Handbook (2001), states, in regard to recommended path markings: *"Shared-use paths should never be designed to 'force' bicyclists to stop or slow at an intersection through the use of a physical barrier or sudden alignment changes. Such obstructions place all path users at potential risk and are especially hazardous to path users at night."* Therefore, obstructions and radical path realignment at intersections to slow or stop trail traffic are not recommended. Speed bumps/humps are considered obstacles to bicycles, can damage fragile bicycle wheel frames and so are not recommended.

Bicycle lanes separated from vehicles and pedestrians at intersections have been installed at UC Davis and several locations in the Netherlands. The experience in the Netherlands found that separate bicycle paths are considered desirable under heavy motor vehicle traffic conditions, but undesirable along streets with low volumes of motor vehicles due to lack of compliance.[2] UC Davis has also instituted the use of a bicycle signal head. It has been approved for use where large volumes of bicycle traffic cross vehicular traffic, primarily at mid-block locations. The special signals provide cyclists with their own separate cycle phase to cross a busy arterial. In one

[2] European Approaches to Bicycle and Pedestrian Facility Design, Federal Highway Administration, 1995.

location, where bicycle crossing volumes were over a thousand an hour in peak times, bicycle collision rates were dramatically reduced after the installation of the separate cycle phase. However, the higher vehicle collision rates prior to installation at this intersection has been at least partially attributed to the roadway profile which included two way bike paths on both sides of the arterials, while one of the paths terminates on one side of the crossing while on the other side it continues.[3] None of the study intersections involves bicycle crossings of major arterials nor do they experience high accident rates. For these reasons, the use of this type of special signal was not further pursued.

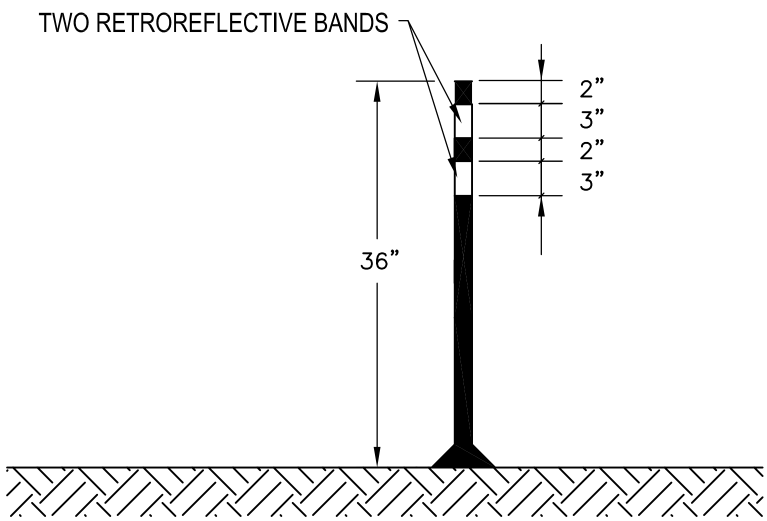
[3] Evolution of a Cyclist-Friendly Community, The Davis Model, David Takemoto-Weerts, 2003



NOTES
1. For skewed crosswalks, position the lines parallel to the traffic lane.

2. Install Crosswalk Line in shoulder area only when adjacent to sidewalk or separate walkway.

Standard Crosswalk Pattern



Hinged Tubular Marker Detail

Figure 4
Crosswalk, Stop Bar, and Tubular Marker Details

Burke-Gilman Trail Signage Plan

The Transpo Group

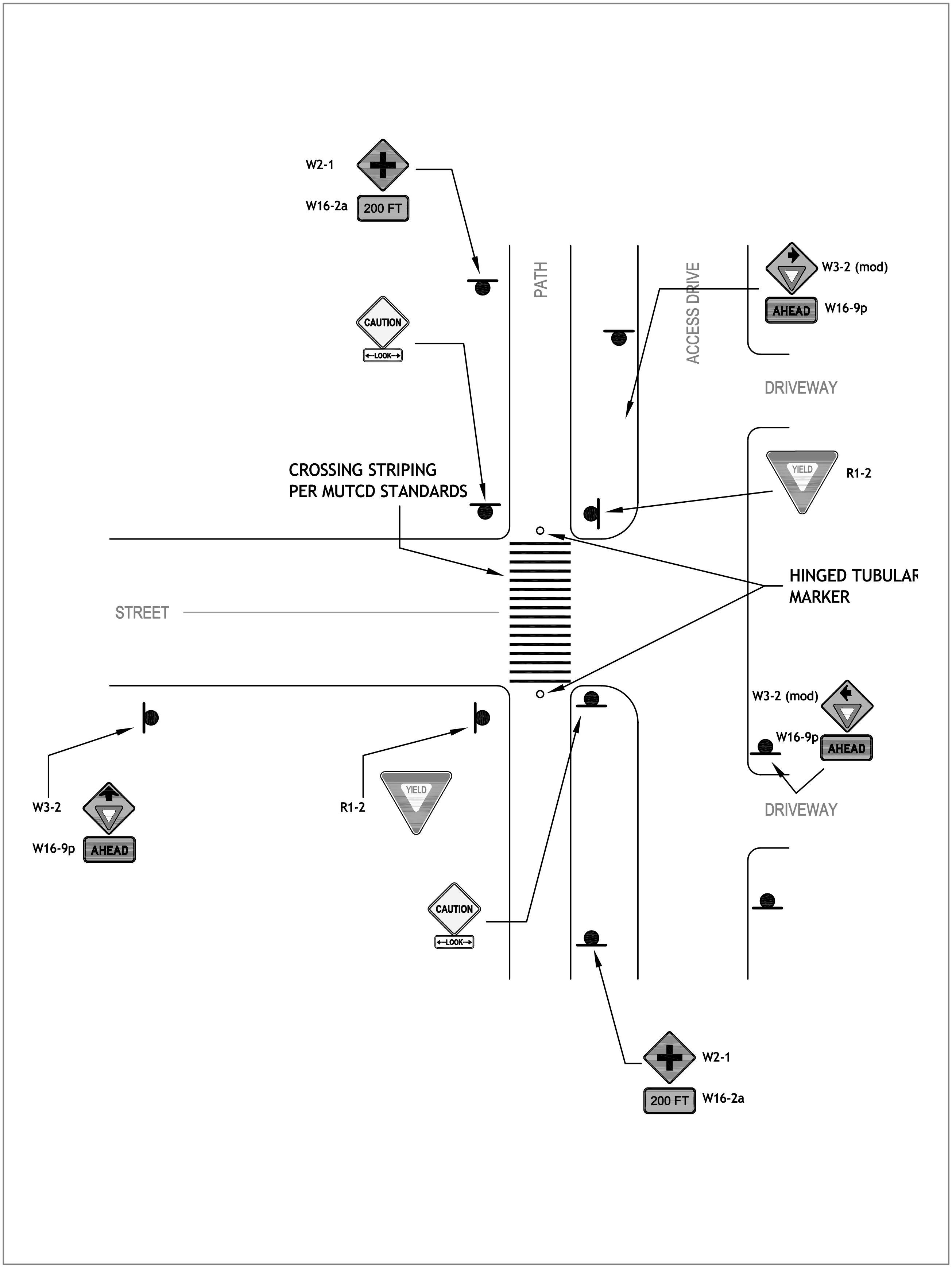


Figure 5

Path/Residential Access Drive- Yield Control

Burke-Gilman Trail Signage Plan

The Transpo Group

M:\03\03292 Burke-Gillman Trail\Graphics\control_scenarios <B> robertm 03/04/05 16:29

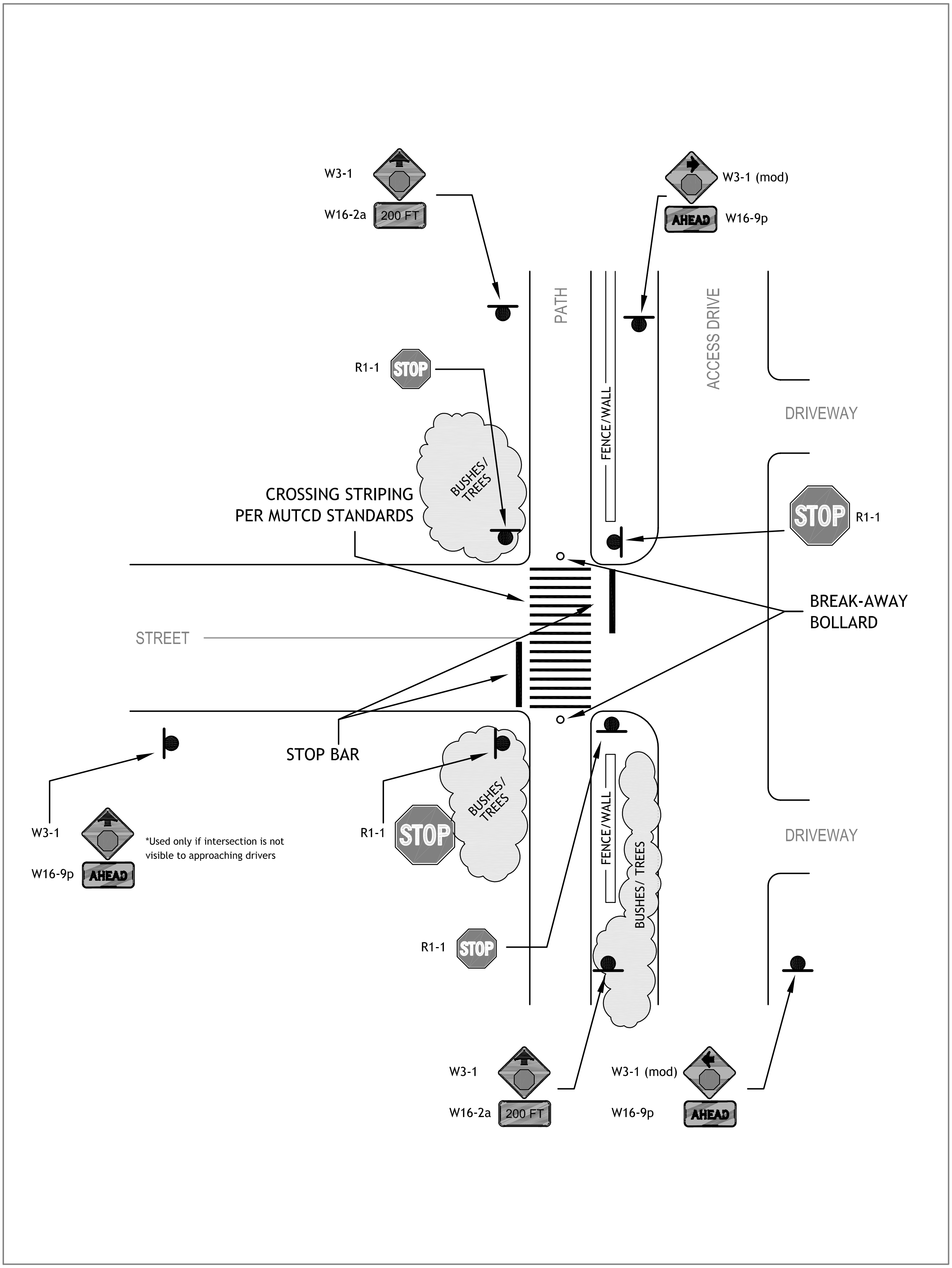


Figure 6

Path/Residential Access Drive Intersection - All-way Stop

Burke-Gilman Trail Signage Plan

The Transpo Group

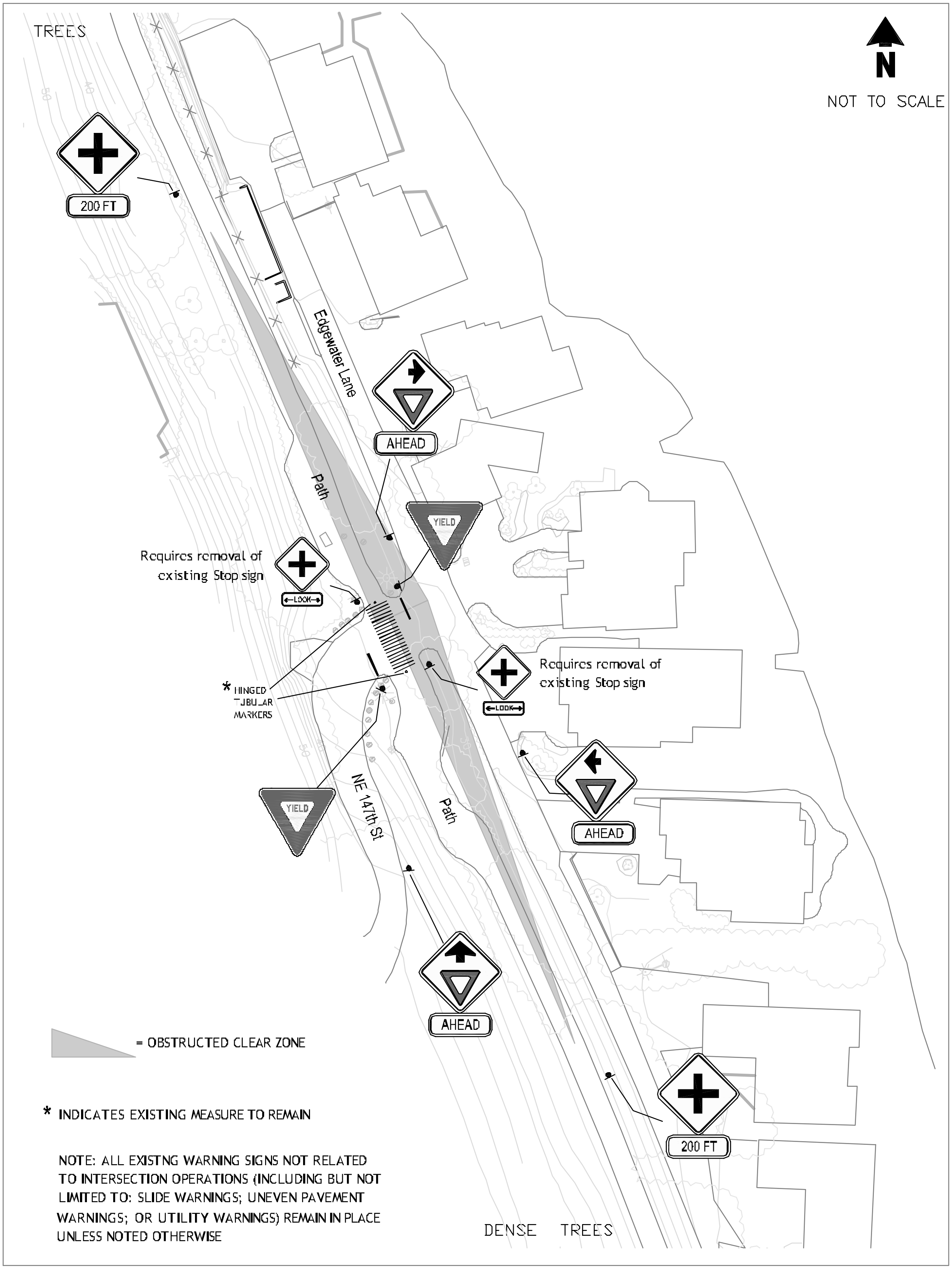


Figure 7
Intersection 1 Signage Plan

Burke-Gilman Trail Signage Plan

The Transpo Group

M:\03\03292 Burke-Gillman Trail\Graphics\SIGNAGE_PLAN03 <A> robertm 11/10/04 13:32

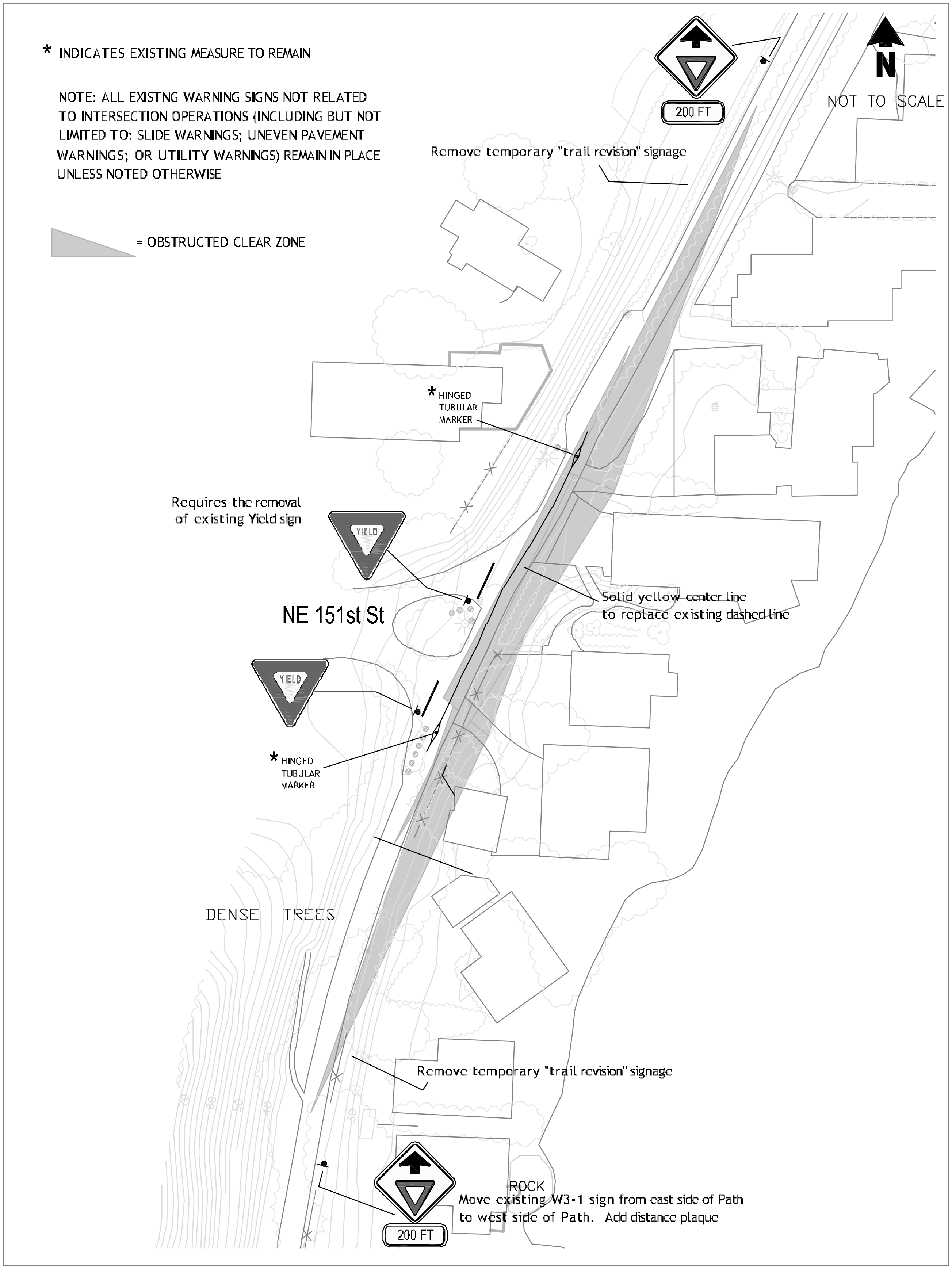


Figure 8

Intersection 2 Signage Plan

Burke-Gilman Trail Signage Plan

The Transpo Group

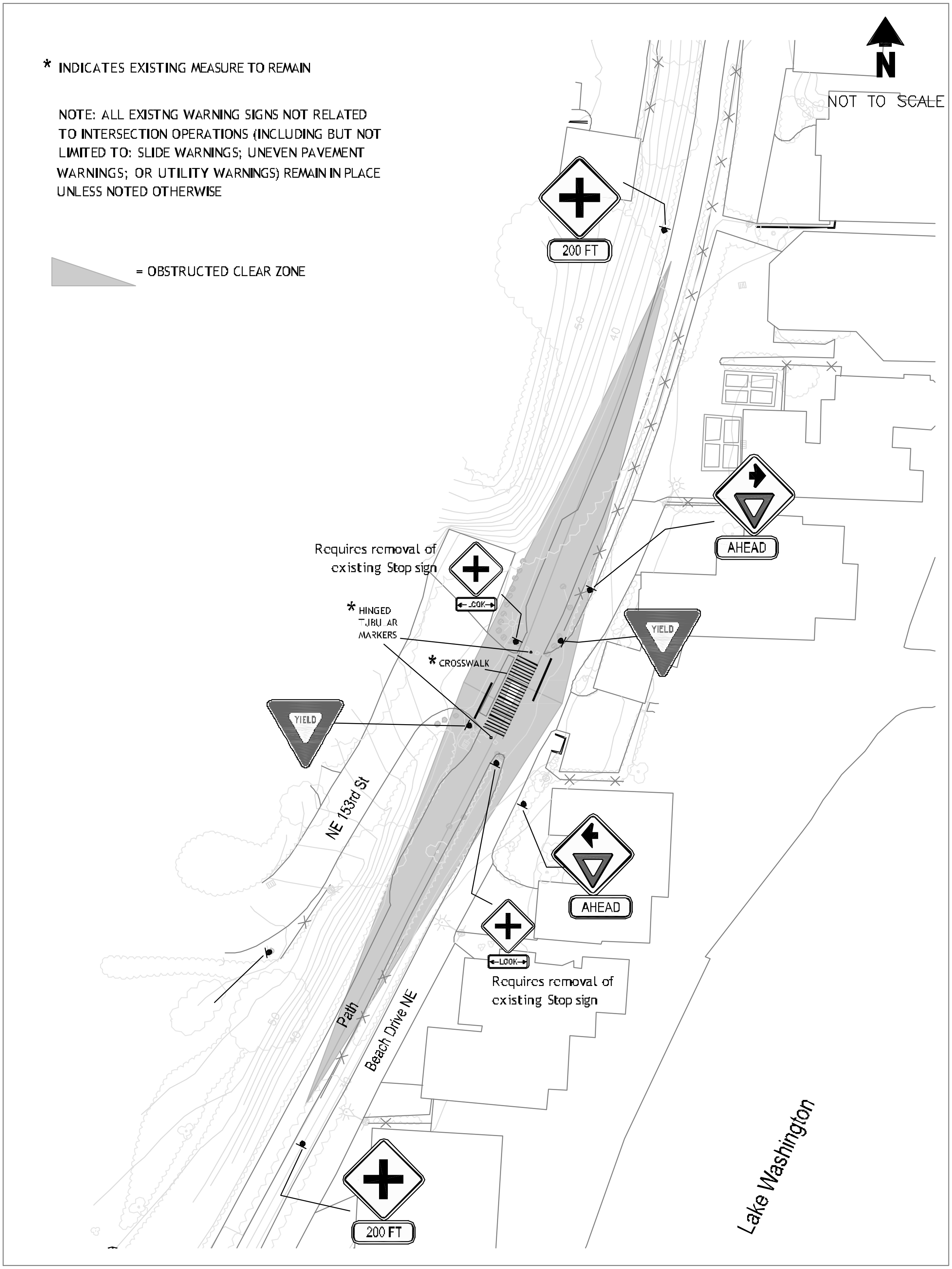


Figure 9

Intersection 3 Signage Plan

Burke-Gilman Trail Signage Plan

The Transpo Group

M:\03\03292 Burke-Gillman Trail\Graphics\SIGNAGE_PLAN03 <B> robertm 11/10/04 13:31

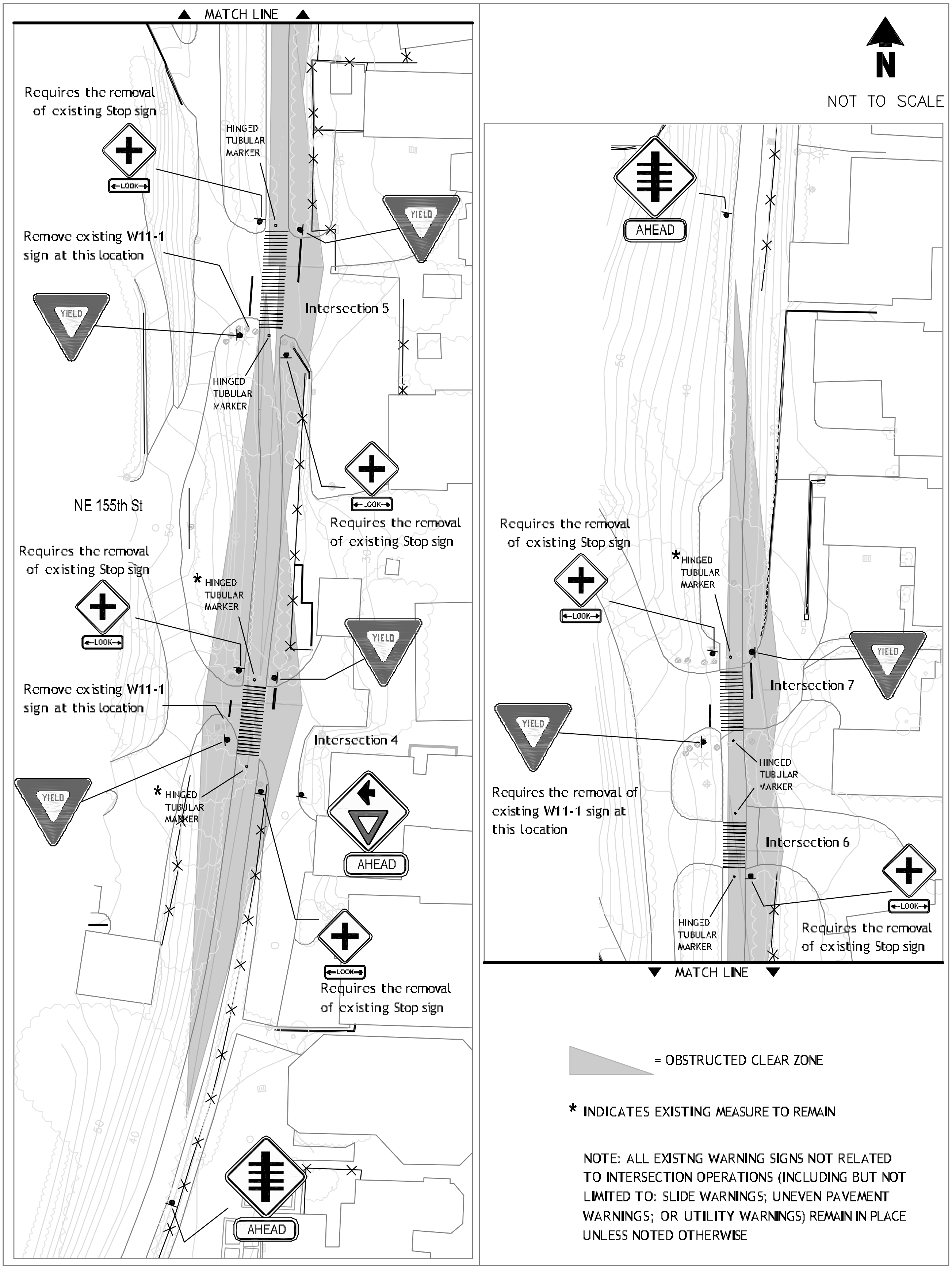


Figure 10

Intersections 4-7 Signage Plan

Burke-Gilman Trail Signage Plan

The Transpo Group

M:\03\03292 Burke-Gillman Trail\Graphics\SIGNAGE_PLAN04 <A> robertm 11/10/04 13:35

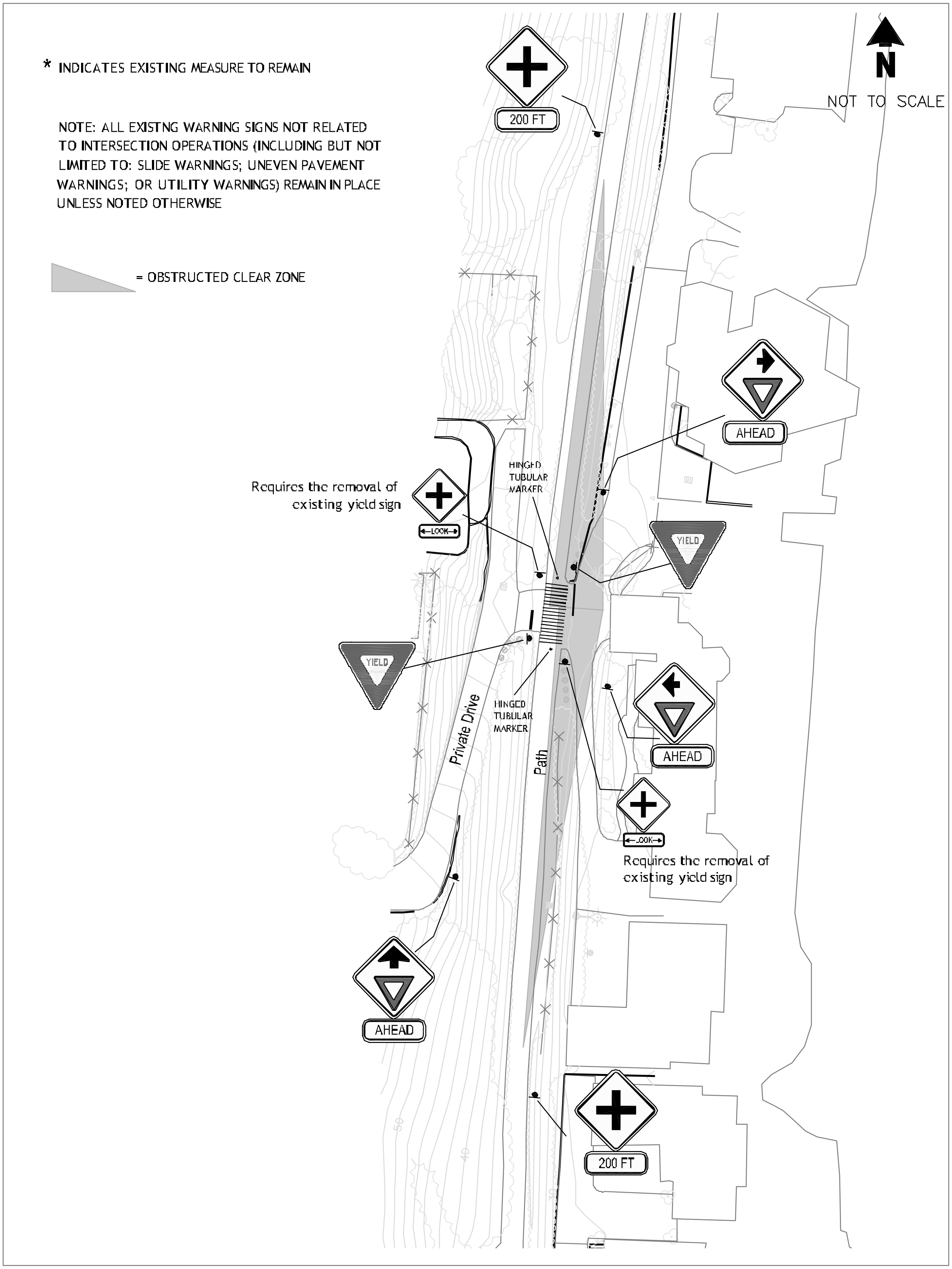


Figure 11

Intersection 8 Signage Plan

Burke-Gilman Trail Signage Plan

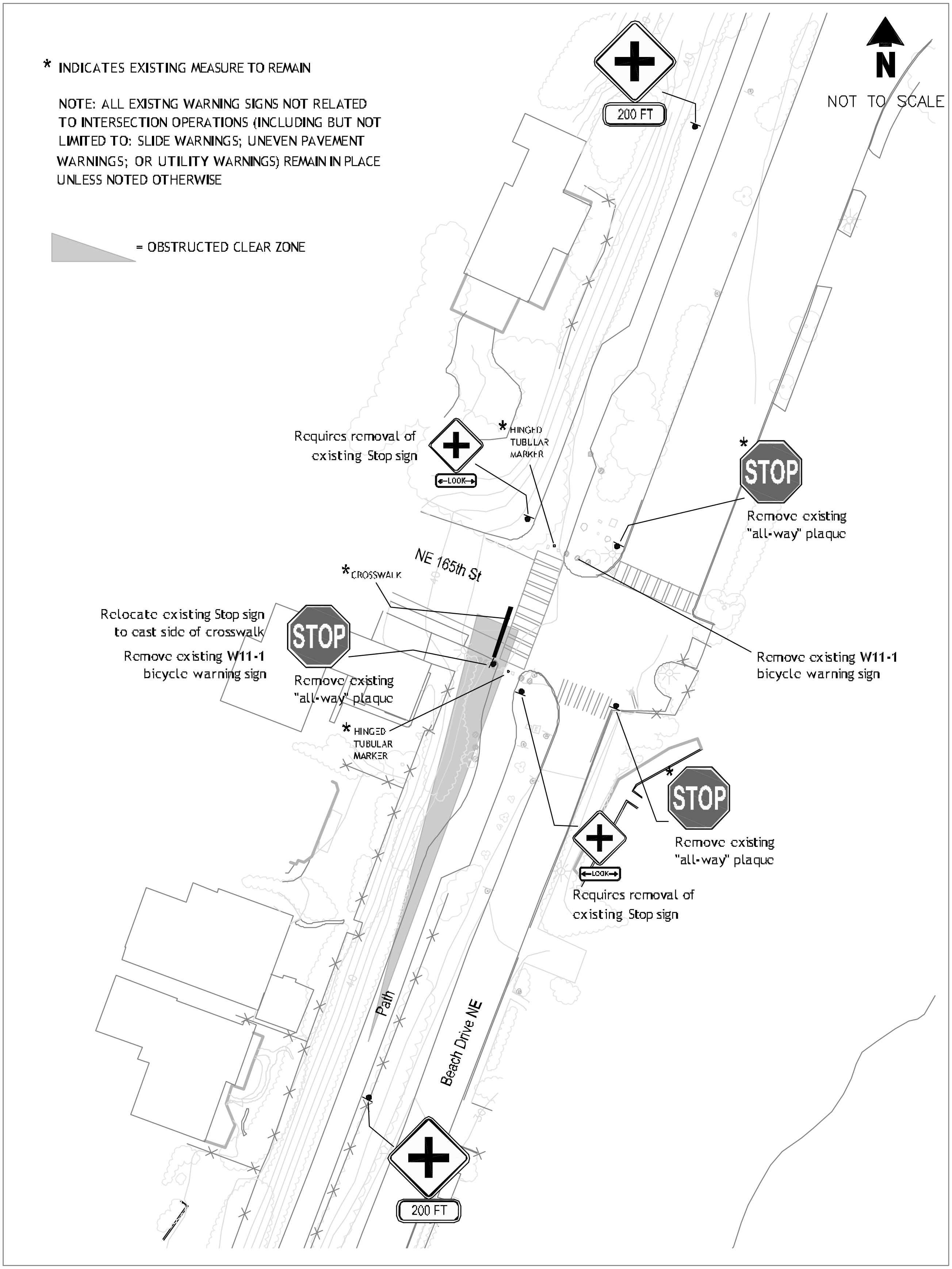


Figure 12
Intersection 9 Signage Plan

Burke-Gilman Trail Signage Plan

The Transpo Group

M:\03\03292 Burke-Gillman Trail\Graphics\SIGNAGE_PLAN03 <D> robertm 11/10/04 13:33

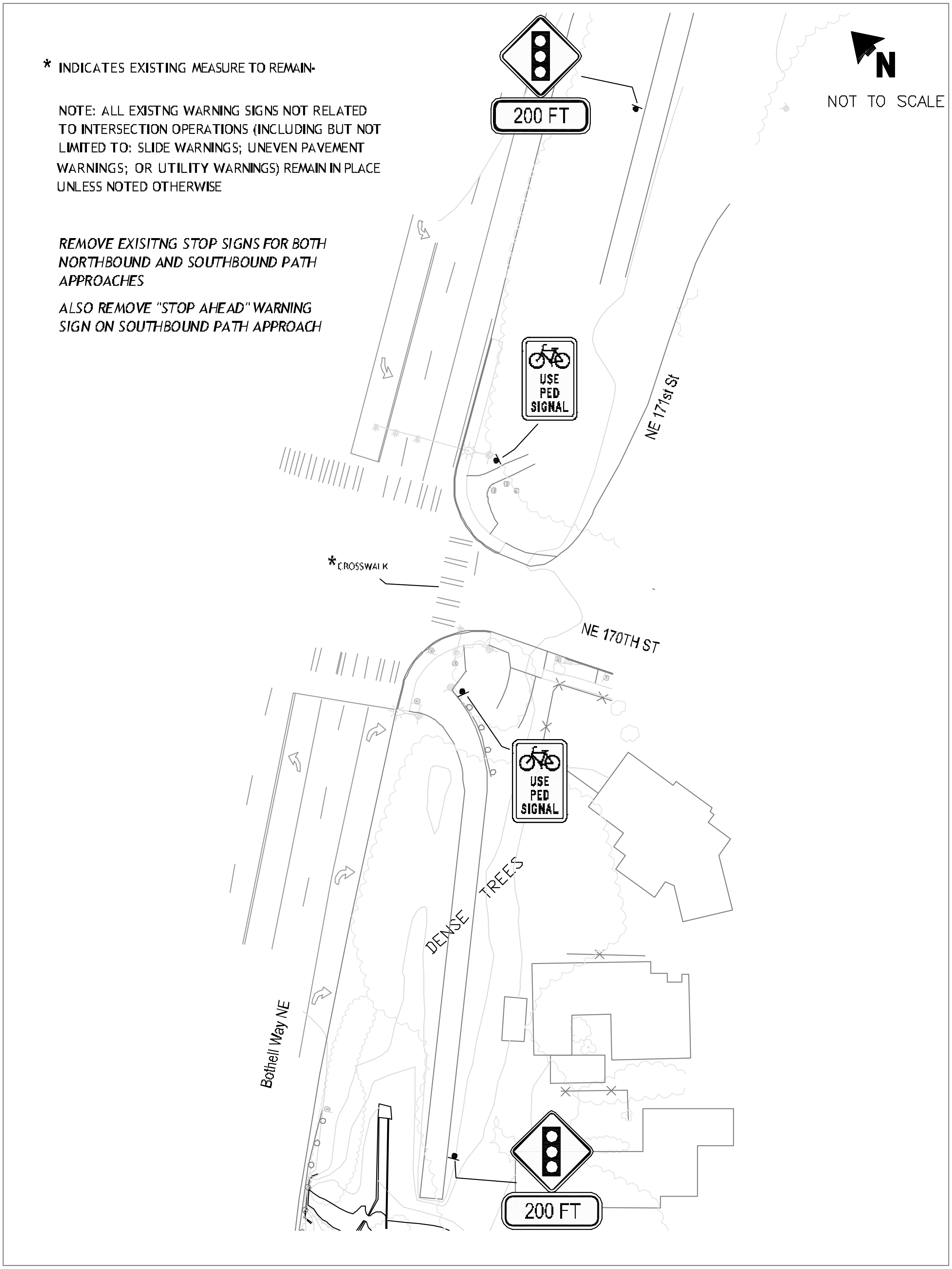


Figure 13

Intersection 10 Signage Plan

Burke-Gilman Trail Signage Plan

The Transpo Group

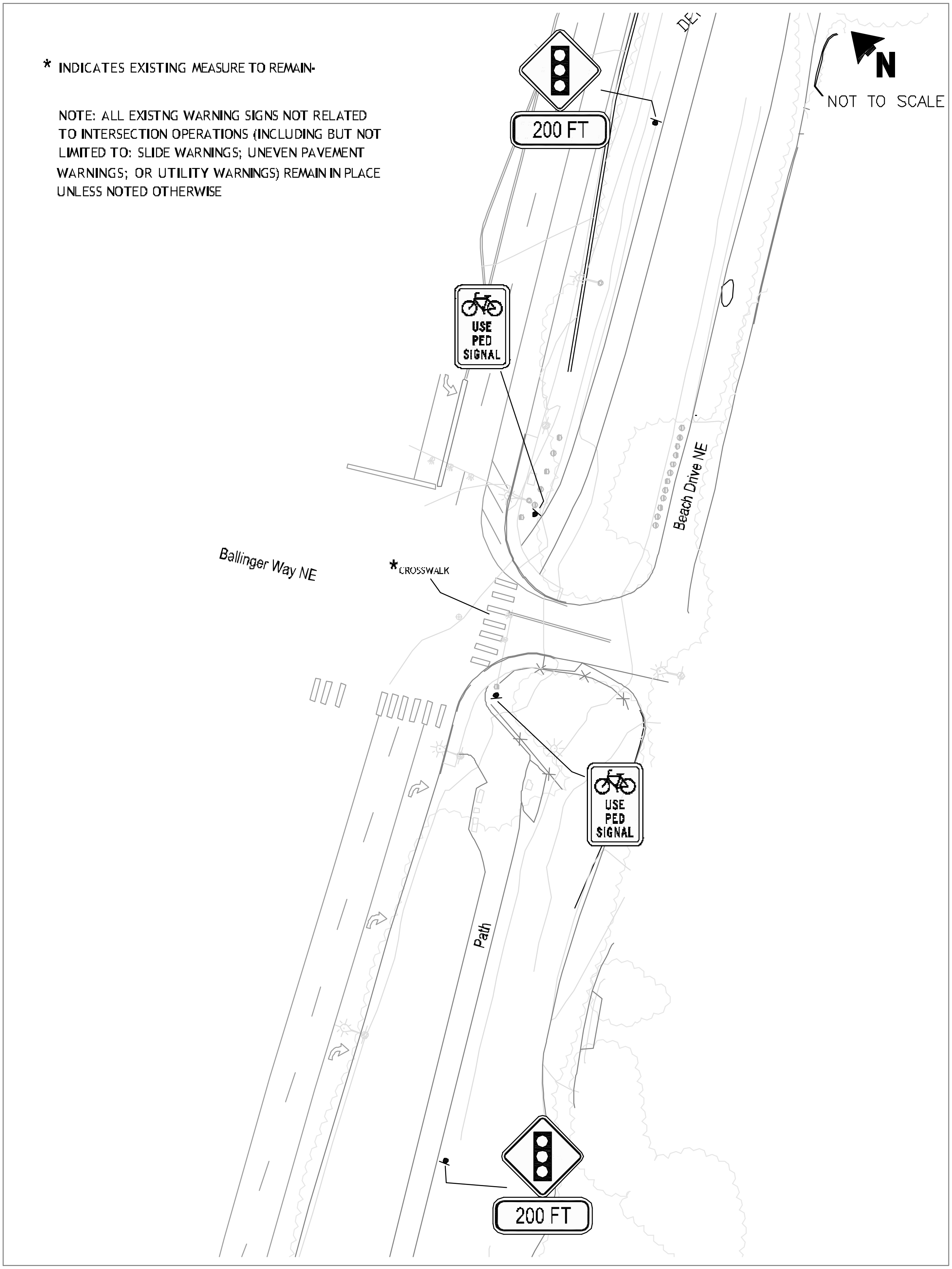


Figure 14

Intersection 11 Signage Plan

Burke-Gilman Trail Signage Plan

M:\03\03292 Burke-Gillman Trail\Graphics\SIGNAGE_PLAN03 <F> robertm 11/10/04 13:34

ATTACHMENT 1 Burke-Gilman Trail Data
ATTACHMENT 2 Speed Data Collection Sampling Methodology

Attachment 1. Bicycle Stop Compliance

	Date	Total Bikes	Bikes Stop	Compliance
NB	2-Jun	1076	19	1.8%
	3-Jun	1179	25	2.1%
	5-Jun	1205	31	2.6%
SB	2-Jun	966	21	2.2%
	3-Jun	1074	26	2.4%
	5-Jun	1151	32	2.8%
Total	2-Jun	2042	40	2.0%
	3-Jun	2253	51	2.3%
	5-Jun	2356	63	2.7%

Location 1

	Wednesday (6/2)				Thursday (6/3)				Saturday (6/5)			
	NB	SB	Tot	% of Total	NB	SB	Tot	% of Total	NB	SB	Tot	% of Total
Peds	95	114	209	17%	115	107	222	16%	92	96	188	13%
Bike	521	459	980	78%	564	527	1091	80%	610	574	1184	79%
Skate	12	10	22	2%	5	3	8	1%	5	5	10	1%
Other	26	25	51	4%	22	18	40	3%	57	57	114	8%
Total	**654**	**608**	**1262**	**100%**	**706**	**655**	**1361**	**100%**	**764**	**732**	**1496**	**100%**

Location 2

	Wednesday (6/2)				Thursday (6/3)				Saturday (6/5)			
	NB	SB	Tot	% of Total	NB	SB	Tot	% of Total	NB	SB	Tot	% of Total
Peds	91	95	186	14%	94	95	189	14%	112	114	226	16%
Bike	555	507	1062	83%	615	547	1162	85%	595	577	1172	83%
Skae	12	13	25	2%	6	7	13	1%	12	8	20	1%
Other	4	6	10	1%	0	0	0	0%	0	0	0	0%
Total	**662**	**621**	**1283**	**100%**	**715**	**649**	**1364**	**100%**	**719**	**699**	**1418**	**100%**

It was desired to estimate the time mean speed with a confidence of ± 1 mph, with 95% confidence. In practice, many highway speed studies allow for a range of ± 5 mph, but these roadways typically have a mean speed over 40 mph. Given that the trail had a sample mean of 14 mph, the preferred range was reduced to ± 1 mph. The sample size for the speed study was calculated as outlined below, and resulted in a size of just under 200 counts required to estimate the speed with this level of confidence. All formulas refer to McShane, William R, and Roess, Roger P, *Traffic Engineering*, Prentice Hall, Englewood Cliffs, New Jersey, 1990.

Step 1

Compute an estimate of the mean (x) and the standard deviation (S) from a sample set collected. In this case, 100 samples were collected and used to compute x and S. The value for x was 14, and for S 6.8, as calculated for the original 100 samples

Step 2

Using Equation (7-7), with S in place of σ, and a tolerance of 1 mph, results in a sample size (N) of 178 samples.

Based on this calculation, 200 samples were collected and a new time mean speed of 14 mph was calculated.

The original 100 samples were collected as two 50 sample sets corresponding to the two directions of travel on the trail. As further verification of our results, we completed **Step 1** and **Step 2** on the individual sample sets. For the two uni-directional sample sets, the sample size required to estimate the speed with ± 1 mph, with 95% confidence, came out to 88 and 99 samples. These resulted in a total of 187 samples, well under the 200 that were collected.

	SouthBound		
Speed	No./ Count	Multiplier	For Variance
7	1	7	54.1696
8	1	8	40.4496
9	1	9	28.7296
10	1	10	19.0096
11	4	44	180.6336
12	3	36	50.1264
13	7	91	90.6304
14	6	84	4.6656
15	8	120	26.2144
16	7	112	131.7904
17	4	68	111.5136
18	5	90	331.24
19	1	19	21.5296
20	1	20	31.8096
Total	50	718	1122.512
Estimate of Mean		14.36	
Estimate of Variance (S2)			22.90840816
Estimate of standard dev (S)			4.786272889

	NorthBound		
Speed	No./ Count	Multiplier	For Variance
7	0	0	0
8	2	16	127.2384
9	2	18	86.1184
10	3	30	119.2464
11	4	44	111.5136
12	6	72	96.8256
13	6	78	14.7456
14	8	112	8.2944
15	4	60	29.5936
16	8	128	356.4544
17	3	51	101.6064
18	3	54	171.0864
19	1	19	28.7296
20	0	0	0
Total	50	682	1251.4528
Estimate of Mean		13.64	
Estimate of Variance (S2)			25.53985306
Estimate of standard dev (S)			5.05369697

	Total		
Speed	No./ Count	Multiplier	For Variance
7	1	7	49
8	3	24	324
9	3	27	225
10	4	40	256
11	8	88	576
12	9	108	324
13	13	169	169
14	14	196	0
15	12	180	144
16	15	240	900
17	7	119	441
18	8	144	1024
19	2	38	100
20	1	20	36
Total	100	1400	4568
Estimate of Mean		14	
Estimate of Variance (S2)			46.14141414
Estimate of standard dev (S)			6.792747172

From Traffic Engineering (McShane/Roess)

SouthBound	NorthBound	Total
95% confidence bounds of mean =	95% confidence bounds of mean =	95% confidence bounds of mean =
13.03331 to 15.68668716	12.239187 to 15.04081333	12.668622 to 15.33137845

For 95% confidence of mean speed within 1 mph, sample size = (1.96*S / 1mph)^2

SouthBound	NorthBound	Total
Sample Size = 88.0049408	Sample Size = 98.11389952	Sample Size = 177.2568566